Maine Department of Environmental Protection
Bureau of Land & Water Quality
O&M Newsletter
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A monthly newsletter for wastewater discharge licensees, treatment facility operators, and associated persons

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An Introduction to Wastewater Biology

The following is a continuation of An Introduction to Wastewater Biology taken from Environmental Training Consultants, 1994, "Activated Sludge Operations for Pulp & Paper Mills"

Individual microorganisms grow; that is, they increase their cell mass, although cell size is quiet limited. After maximum cell size is reached, the cell divides into two new cells, identical in all respects. These two new cells increase in size and, in turn, divide themselves as maximum size is reached. Some of the more complex microorganisms have more complex reproductive processes, but bacteria, protozoa and fungi all reproduce in this manner. This type of reproduction is called binary fission. Under optimum conditions, bacteria cells may divide every 20 to 30 minutes. That means that the total number of cells and the total mass of cells may double every half hour.

This rapid rate of reproduction is called logarithmic growth and is not desirable in wastewater treatment processes because the bacteria in this growth phase are dispersed and do not settle well in a secondary clarifier. Effluent from such a plant is turbid and high in BOD_5 and TSS.

Logarithmic growth is seldom experienced in activated sludge operations unless the plant is undergoing start-up or recovering from an upset condition. For rapid reproduction to occur there must be an abundance of food (BOD_5), or a small amount of biomass relative to the amount of food. This is often referred to as a high food to microorganism (F/M) ratio.

Since most microorganisms are too small to consider individually, it is more convenient to describe the growth of microorganisms in terms of population of individuals or cultures and to speak of them in terms of total mass of cellular material rather than number. Since microorganisms do not always find themselves in optimum conditions, it is of value to know how they react to different environmental conditions. Environmental conditions are sometimes referred to as "growth pressures" because they influence the rate to microbial growth as well as the diversity and predominance of microorganisms.

One of the most critical environmental factors, of course, is the availability of nutrients or food. Since the food supplies both energy and materials to the organisms, the organisms would be expected to grow at different rates under different nutrient conditions.

When microorganisms find themselves in an abundance (excess) of food, that is, food is present beyond that which the cell can assimilate, reproduction occurs at logarithmic rate. The log growth phase continues until the food is depleted.

As more and more food is used up, the reproduction rate slows down considerably. This period of decreasing rate of growth is called the declining growth phase. When the concentration of available food has been exhausted, reproduction ceases. Cells are still alive, although they are starving. The microorganisms use organic material within their own cells as a source of energy.

This is the endogenous phase. During this phase, the total mass of microorganisms begins to slowly decrease as the cells use up their stored reserves and begin to die. BOD_5 removal is usually very good when a biomass is in endogenous respiration because the bugs have oxidized all of the available food. As a general rule, conventional activated sludge facilities are operated to achieve endogenous respiration within the detention time of the aeration basin. This assures that BOD_5 has been assimilated and oxidized by the biomass before sludge enters the secondary clarifier.

The condition in which food is abundant in great excess relative to the microorganisms (log growth) is an unusual one. Ordinarily, this only occurs at:

- start-up;
- upon recovery from an upset in which solids washed out significantly;
- when a spill of high strength organic material passed into the aeration basin.

In any of these cases, activated sludge performance suffers because the growth phase of the biomass is stimulated by a high food to microorganism ratio (F/M) and the organisms enter log growth – a phase where poor settling is common.

Operators attempt to adjust the F/M in an effort to control or stabilize the growth rate of the bugs in the system. Since F/M controls growth rate, and growth rate affects the sludge quality and bio-flocculation, F/M is a significant growth pressure. Floc-forming bacteria are only flocculent when in a stationary phase of growth (declining or endogenous). When floc-forming bacteria grow in high F/M conditions they become dispersed (single cells) and wash out of the secondary clarifier. Consequently, effluent quality may suffer during high F/M conditions.

A properly flocculation biomass is composed of a community of bacteria. Approximately two-thirds are flocculent and one-third is non-flocculent. Greater than 90% of the organisms are gram negative rods. More than 80% are strict aerobes, the rest are facultative.

The total cell density ranges from 10^{11} – 10^{12} bacterial cells per milliliter. Of this number, approximately 10^{8} -10^{9} cells/mL are viable. Activated sludge floc typically shows a viability of 3 – 20%.

When the F/M is less than 0.5 (where conventional activated sludge plants operate) viability ranges from 1 – 5%. The majority of cells in activated sludge are not alive. They are part of the flocculent biomass, but the dead organisms do not metabolize organic material. The task of BOD_5 removal is accomplished by the viable fraction of the biomass.

It is common practice to calculate F/M ratio by using the volatile fraction of the mixed liquor as an estimate of the microorganisms present. In light of the fact that microbial viability varies, the F/M calculation may be a little misleading at times.

Don Albert

For Practice

1. Which of the following wastewater characteristics can be easily monitored on a continuous basis?
   a. BOD
   b. Mercury
   c. pH
   a. Coli form Bacteria

2. Part of the required maintenance for capillary or liquid thermometers includes checking for:
   a. corrosion
   b. high fluid level
   c. loose connections
   d. leaks

3. Before making a final decision, all information pertaining to the situation should be:
   a. analyzed.
   b. discussed with everyone in the plant.
   c. written down on an approved form.
   d. none of the above.

4. The wastewater treatment process which commonly uses sludge re-aeration is called:
   a. conventional activated sludge.
   b. contact stabilization.
   c. extended aeration.
   d. trickling filter.

Approved Training

August 30 – September 27, 2006 in Caribou, ME – Class II, III & IV Water Distribution Exam Prep Course – sponsored by MRWA – (207) 729-6569 - Approved for 9.5 hours (note: wastewater operators must attend specific parts of the course for credit.)
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October 4, 2006 in Norway, ME – Class II Water Treatment Exam Review – sponsored by MRWA – (207) 729-6569 - Approved for 3.75 hours
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October 10, 2006 in Ellsworth, ME – Class III and IV Water treatment Exam Review – sponsored by MRWA – (207) 729-6569 - Approved for 2.5 hours
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October 11, 2006 in Belfast, ME – Class II Water Treatment Exam Review – sponsored by MRWA – (207) 729-6569 - Approved for 3.75 hours
*****
October 12, 2006 in Caribou, ME – Class III and IV Water treatment Exam Review – sponsored by MRWA – (207) 729-6569 - Approved for 2.5 hours
*****
October 17, 2006 in Easton, ME – Simplifying your Water/Wastewater Process Monitoring – sponsored by MRWA – (207) 729-6569 - Approved for 5.0 hours

October 18, 2006 in Caribou, ME – Verifying your Water/Wastewater Treatment Process – sponsored by MRWA – (207) 729-6569 - Approved for 4.0 hours
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October 19, 2006 in Kittery, ME – Simplifying your Water/Wastewater Process Monitoring – sponsored by MRWA – (207) 729-6569 - Approved for 5.0 hours
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October 20, 2006 in York, ME – Verifying your Water/Wastewater Treatment Process – sponsored by MRWA – (207) 729-6569 - Approved for 4.0 hours
*****
October 26, 2006 in Dixfield, ME – Work Zone Traffic Control – sponsored by MRWA – (207) 729-6569 - Approved for 5.5 hours
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November 1 & 2, 2006 in Presque Isle, ME – North Country Convention – Sponsored by JETCC – (207-253-8020 – Approved for up to 12 hours
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Note: JETCC stands for Joint Environmental Training Coordinating Committee
MRWA stands for Maine Rural Water Association
MWWCA stands for Maine Wastewater Control Association
NEIWPCC stands for New England Interstate Water Pollution Control Commission
WPETC stands for Wright Pierce Environmental Training Center.

10th Biannual North Country Convention to be held in November

The biannual two-day training conference for operators in Northern Maine will be held this year on November 1st and 2nd in Presque Isle. As usual, 12 or more hours of approved training on a variety of topics will be presented over the two days. The North Country Convention has always been well attended by operators from the northern part of the state. It offers not only an opportunity to attend training sessions but also to meet with product vendors and exchange ideas with each other. For more information about the North Country Convention, contact JETCC at 253-8020.

Answers to *For Practice:*

1. c pH can easily be monitored using an electronic probe that can, except for occasional cleaning and calibration, be used continuously. BOD, Coli form Bacteria and Mercury are tests that must be performed in a laboratory on a discrete sample

2. d All capillary thermometers contain liquid. If the liquid leaks out of the thermometer, inaccurate readings can result.

3. a Before making any final decision, all the information available should be analyzed. It may not be possible or necessary to discuss the decision with everyone at the plant and it may not necessary to write everything down on an approved form.

4. b Contact Stabilization uses a contact tank where the raw wastewater is combined with the return sludge for a short period, usually 30 minutes to 1 hour. The sludge is settled in a secondary clarifier and then pumped to a re-aeration tank where it sits under aerobic conditions for 4 to 8 hours before being pumped back to the contact chamber. Conventional Activated sludge and Extended Aeration systems return the sludge directly from the clarifiers to the aeration basins without the intermediate re-aeration tank. Tricking filters do not normally have any aeration basins.